PROPELLER WITH VARIABLE GEOMETRY AND METHOD FOR VARYING GEOMETRY OF A PROPELLER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. §119(e) of United States Provisional Application No. 60/442,129, filed January 24, 2003.

FIELD OF THE INVENTION

[0002] This invention relates to the construction of propellers. More specifically it relates to a propeller having propeller blades with variable dimensions. Even more specifically, the present invention relates to an aircraft or waterborne or submersible craft having a propeller whose size and shape can be modified.

BACKGROUND OF THE INVENTION

[0003] Aircraft and waterborne and submersible vessels are typically constructed having propellers of fixed dimensions. The dimensions chosen affect the amount of force created by the propeller per unit torque on the propeller shaft. A greater diameter is desired for many applications. However, a fixed diameter propeller is limited in size by, for example, the need for an aircraft to land and for a waterborne or submersible craft to enter port.

[0004] Clearly, then, there is a longfelt need for a vessel having a propeller with variable dimensions.

SUMMARY OF THE INVENTION

[0005] The present invention broadly comprises a propeller having a blade assembly with a plurality of linking members operatively connected to change dimensions of the blade assembly as the linking members are moved with respect to one another. It further includes a blade surface operatively arranged to cover at least a portion of the blade assembly and to change shape in response to the changes in the dimensions for the blade assembly.

[0006] A general object of the present invention is to provide a propeller having variable dimensions.

[0007] Another object of the present invention is to provide a propeller blade having variable dimensions.

[0008] Yet another object of the present invention is to provide a propeller having a variable shape.

[0009] Still another object of the present invention is to provide a propeller blade having a variable shape.

[0010] These and other objects, features and advantages of the present invention will become readily apparent to those having ordinary skill in the art upon a reading of the following detailed description of the invention in view of the drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The nature and mode of operation of the present invention will now be more fully described in the following detailed description of the invention taken with the accompanying drawing figures, in which:

Figure 1 is a perspective view of the present invention propeller in an expanded configuration;

Figure 1A is a perspective view of the propeller shown in Figure 1 with a flexible member covering the folding lattice;

Figure 2 is a perspective view of the propeller with the folding lattice in a contracted configuration;

Figure 2A is a perspective view of the propeller shown in Figure 2 with a flexible membrane covering the folding lattice;

Figure 3 is a top view of the propeller shown in Figure 1;

Figure 4 is a top view of the propeller shown in Figure 2;

Figure 5A is an expanded or flattened view of a second embodiment of the propeller in a contracted configuration;

Figure 5B is an expanded view of the second embodiment in an expanded configuration;

Figure 6A is a front view of a truss for the second embodiment in a contracted configuration (Prior Art);

Figure 6B is a back view of the truss for the second embodiment in a contracted configuration (Prior Art);

Figure 6C is a front view of the truss in a partially expanded/contracted configuration (Prior Art);

Figure 6D is a front view of the truss in an expanded configuration (Prior Art);

Figure 7 is a back view of a plate assembly, in a contracted configuration, corresponding to the area shown in Figure 5A; and,

Figure 8 is a back view of the plate assembly, in an expanded configuration, corresponding to the area shown in Figure 5B.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0012] It should be appreciated that, in the detailed description of the invention that follows, like reference numbers on different drawing views are intended to identify identical or similar structural elements of the invention in the respective views.

[0013] Furthermore, it is understood that this invention is not limited to the particular methodology, materials and modifications described and as such may, of course, vary. It is also understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention, which is limited only by the appended claims.

[0014] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention

belongs. Although any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the invention, the preferred methods, devices, and materials are now described.

[0015] The invention broadly comprises a propeller with a blade assembly having variable dimensions. The invention further comprises an adjustable blade surface that changes size and shape and covers at least a portion of the blade assembly. The blade assembly may be a radial extension/retraction truss structure as disclosed by United States Patent No. 5,024,031 (Hoberman), incorporated by reference herein.

[0016] Figure 1 is a perspective view of the present invention propeller **10** in an expanded configuration. Shaft **20** includes a key **22** running the length of shaft **20**. However, any number of key members may be used. Shaft **20** is connected to member **24,** which delivers torque from a vehicle power plant (not shown) to shaft **20**. Collars **30** radially surround shaft **20** and include a slot that engages key **22**, preventing collars **30** from rotating about shaft **20** as power is applied to member **24** to rotate shaft **20**. However, it should be readily apparent to one skilled in the art that other means of preventing rotation of collars **30** may be used, and such means are within the spirit and scope of the invention as claimed. Collars **30** can slide longitudinally along shaft **20**. Each collar **30** has a collar extension **32** with aperture **34**. Respective extensions **32** can be located at various radial angles with respect to a radial axis for shaft **20**. The angles can be varied to provide a desired blade pitch, as further described below.

However, it should be readily apparent to one skilled in the art that other angle configurations are possible, and such configurations are within the spirit and scope of the invention as claimed.

[0017] Lattice bars **40** are substantially straight in shape and have a plurality of pivoting connection points **42**, aligned in a straight line. It should be readily apparent to one skilled in the art that other shapes are possible for bars **40**, and that such shapes are within the spirit and scope of the invention as claimed. Collectively, bars **40** form folding lattice **44**. Folding lattice **44** is pivotally connected to respective collar extensions **32** using fasteners **46** that extend through apertures (not shown) in bars **40** and apertures **34** in collar extensions **32**. The connection between collars **30** and bars **40** may have a generous tolerance or may pivot or fold to allow a small amount of rotation about an axis radial from shaft **20** and through the connection. Folding lattice **44** forms the basic structure for a propeller blade as is further described below. Bars **40** may be identical for efficiency of production, or individually designed for operation efficiency or strength, with different cross sections to better approximate typical foil sections when assembled.

[0018] Figure 1 shows each collar **30** with three collar extensions **32,** corresponding to attachment points for three folding lattice **44** assemblies (only one of which is shown). To simplify this presentation, only one folding lattice assembly is shown in Figure 1. It should be readily apparent to one skilled in the art that any number of collar extensions may be used on collars **30**, and that such number of collar extensions is within the spirit and scope of the invention as claimed. Linear actuator **60** is substantially parallel to the longitudinal axis of shaft **20** and is connected to collar extensions **32a** and **32b**. However, it should be readily apparent to

one skilled in the art that actuator **60** can be connected to other or additional collars extensions **32**, and such connections are within the spirit and scope of the invention as claimed. Collar extensions **32a** and **32b** are connected to collars **30a** and **30b**, respectively. Actuator **60** has a body **61** connected to collar extension **32a** and a shaft **62** connected to collar extension **32b**. Actuator **60** moves shaft **62** substantially parallel to the longitudinal axis of shaft **20**. That is, the actuator **60** extends or withdraws shaft **62** with respect to body **61**. In Figure 1, shaft **62** is extended. Movement of shaft **62** causes movement of collars **30a** and **30b** and subsequently, movement of bars **40**. For example, in Figure 1, shaft **62** is extended, causing collars **30a** and **30b** to move further apart along shaft **20**. This movement of collars **30a** and **30b**, in turn, causes bars **40** to unfold, changing the configuration of folding lattice **44**. Specifically, the width of folding lattice **44** (measured substantially parallel to the longitudinal axis of shaft **20**) increases and the length of folding lattice **44** (measured substantially parallel to a radial axis of shaft **20**) decreases. It should be readily apparent to one skilled in the art that additional actuators may be used, and the use of such additional actuators is within the spirit and scope of the invention as claimed. The actuator **60** can be a pneumatic or hydraulic device or a micro-electrical-mechanical system (MEMS), or any other means known in the art. It should be understood that actuator **60** also could be directly connected to lattice bars **40** (not shown). The collars **30** then slide along shaft **20** responsive to the motion of the lattice bars. A rotational actuator may be similarly powered to rotate any adjacent or set of adjacent lattice bars **40** at their common pivot

points **42**. In addition, a multiplicity of actuators can be used and combinations of linear and rotational actuators also are possible.

[0019] Figure 1A is a perspective view of the propeller **10** shown in Figure 1 with a flexible member **50** covering the folding lattice **44**. In Figure 1A, folding lattice **44** is covered by flexible membrane **50**, forming propeller blade **52**. In some embodiments, membrane **50** is urethane. However, it should be readily apparent to one skilled in the art that other flexible materials may be used for membrane **50**, and that these materials are within the spirit and scope of the invention as claimed.

[0020] Figure 2 is a perspective view of the propeller with the folding lattice **44** in a contracted configuration. In Figure 2 actuator **60** is retracted. As a result, collars **30a** and **30b** move toward one another, changing the configuration of folding lattice **44**. Specifically, the width of lattice **44** in Figure 2A (measured substantially parallel to the longitudinal axis of shaft **20**) decreases and the length of lattice **44** (measured substantially parallel to a radial axis of shaft **20**) increases.

[0021] Figure 2A is a perspective view of the propeller **10** shown in Figure 2 with a flexible membrane covering the folding lattice **44**.

[0022] The following discussion should be considered in light of both Figures 1A and 2A. In the retracted aspects, Figure 2A, and the extended aspects, Figure 1A, flexible membrane **50** conforms to the shape of folding lattice **44**. Flexible membrane **50** may be replaced by a

multitude of plates (not shown) attached to folding lattice **44** so as to provide a complete (if not fluid-tight) surface on one or both sides of a blade, in at least two folding lattice **44** positions.

[0023] Figure 3 is a top view of the propeller **10** shown in Figure 1.

[0024] Figure 4 is a top view of the propeller **10** shown in Figure 2. The following discussion should be considered in light of Figures 1 through 4. Figures 3 and 4 illustrate the radial spacing of extensions **32** about successive collars **30** on shaft **20**. For example, moving front right to left in Figure 3, collar extensions **32** on successive collars **30** are positioned further clockwise looking from the right hand end of shaft **20**. One propeller blade is shown in Figures 1-4 for simplicity. However, it should be readily apparent to one skilled in the art to include multiple blades to construct a full propeller.

[0025] Figure 5A is an expanded or flattened view of a second embodiment of the propeller **10** in a contracted configuration.

[0026] Figure 5B is an expanded view of the second embodiment in an expanded configuration. The following description should be considered in light of Figures 5A and 5B. In Figure 5A, expandable blade **400** is shown in a contracted configuration. In this configuration, blade **400** consists of a plurality of contracted areas **402**. Each of areas **402** has four pairs of plates. These pairs of plates partially overlap, as will be more fully described below. The plates are fully described below, however, to give a simplified overview of the areas **402**, plates for only one area **402** are shown. However, it is understood that the following description applies to each of areas **402** in blade **400**. The plates noted in the previous sentence are not labeled and

boundaries between individual plates are not shown. Instead, only the outline of the plates is shown. Note that portions of the plates overlap into neighboring areas **402**. Each area **402** is associated with a truss structure (not shown, but described further below). The plates shown in Figure 5A are connected to a respective truss. Blade **400** is connected to collars **30a** and **30b**.

[0027] Figure 5B shows blade **400** in the expanded configuration. In this configuration, blade **400** is made up of a plurality of expanded areas **410**. Each area **410** corresponds to an area **402**. To aid in understanding the transformation of areas **402** to areas **410**, five areas **410** are shaded in Figure 5B. The second area **410** from the top of the page for Figure 5B corresponds to area **402** in Figure 5A. To form an area **410**, a truss associated with a respective area **402** is expanded, as shown below. The force for this expansion is provided by the movement of collars **30a** and **30b** as is described below, and/or by rotation of any number of adjacent truss elements. As a result, the plates rotate and shift position, resulting in the plates occupying a greater area as shown in Figure 5B. Only the outline of the plates is shown in Figure 5B. The process also works in the reverse direction. That is, the above-mentioned truss can be contracted, causing the plates to rotate and shift position, resulting in the plates occupying a smaller area. A respective area **410** has approximately twice the surface area of a respective area **402**.

[0028] Figure 6A is a front view of a truss **420** for the second embodiment in a contracted configuration (Prior Art).

[0029] Figure 6B is a back view of the truss **420** for the second embodiment in a contracted configuration (Prior Art). The following should be considered in light of Figures 5A,

5B, 6A, and 6B. For each area **402** or area **410**, the respective truss noted above is formed by radial extension/retraction truss structure **420**. The truss structure **420** may be a radial extension/retraction truss structure as disclosed by United States Patent No. 5,024,031 (Hoberman). Figure 6A shows the front of truss **420** and Figure 6B shows the back. It should be understood that the terms "front" and "back" are relative and therefore, fully interchangeable. Mounting members **421** through **424** are shown in Figure 6A and mounting members **425** though **428** are shown in Figure 6B. The above-described pairs of plates are securely attached, one plate each, to a corresponding mounting member as is further described below.

[0030] Figure 6C is a front view of the truss **420** in a partially expanded/contracted configuration (Prior Art).

[0031] Figure 6D is a front view of the truss **420** in an expanded configuration (Prior Art). The following should be considered in light of Figures 5A, 5B, 6A, 6C, and 6D. In Figures 6C and 6D, the front side of truss **420** is shown. However, it is understood that the description that follows is applicable to the backside of truss **420** also. Mounting members **421** through **428** are connected to linking members **450**. Blade link points **431** through **434** are attached to mounting members **421** through **424**, respectively. Blade link points **435** through **438** are attached to mounting members **425** through **428**, respectively. Truss **420** expands and contracts due to the movements of linking members **450** in Figures 6C and 6D. To focus the present description on the essentials of the present invention, only a cursory explanation of the movement of linking members **450** is provided. The reader is referred to the incorporated patent

for further details. Linking members **450** and the mounting members each form a closed loop and have pivoting connection points and pivoting/slotted connections points, enabling the mounting members to execute the relatively complex movements shown in Figures 6C and 6D.

[0032] Linking members **450** move in response to movement of blade link points **431** through **438**. For example, blade link points **433** and **436** could be connected to the collars as shown in Figures 5A and 5B. Then, as the collar link points are moved progressively closer, blade link points **433** and **436** move closer together, causing linking members **450** to pivot, slide, and move further apart with respect to one another. This results in the mounting members rotating and translating through space to realign in the expanded configuration shown in Figure 6D. Thus, the plates attached to the mounting members shift from the configuration shown in Figure 5A to the configuration shown in 5B. Moving the collar link points further apart reverses this process.

[0033] It should be understood that actuator **60** also could be directly connected to linking members **450** (not shown). A rotational actuator may be similarly powered to rotate any adjacent or set of adjacent linking members **450** at their common pivot points. In addition, a multiplicity of actuators can be used and combinations of linear and rotational actuators also are possible.

[0034] Figure 7 is a back view of a plate assembly **450**, in a contracted configuration, corresponding to the area **402** shown in Figure 5A. The following discussion should be considered in light of Figures 5A, 6A, 6B, and 7. The two plates in each of the four pairs of

plates noted in the descriptions for Figure 5A are matched in size and shape. However, it should be readily apparent to one skilled in the art that the sizes and shapes need not be matched, and that such variation in sizes and shapes are within the spirit and scope of the invention as claimed. For each pair, one plate is securely attached to a mounting plate on the front side of truss **420** and the remaining plate is securely attached to a mounting plate on the back side of truss **420**, as is further described below. A back side of truss **420** is shown in Figure 7, although it is understood that a front side could also be shown for the following description. The first pair of plates includes plates **460a** and **460b**, roughly trapezoidal in shape. Plate **460a** is attached to mounting member **426** and plate **460b** is attached to mounting member **421** (not shown). The second pair includes plates **461a** and **461b**, roughly triangular in shape. Plate **461a** is attached to mounting member **424** (not shown) and plate **460b** is attached to mounting member **427**. The third pair includes plates **462a** and **462b**, roughly triangular in shape. Plate **462a** is attached to mounting member **425** and plate **462b** is attached to mounting member **422** (not shown). The fourth pair includes plates **463a** and **463b**, roughly trapezoidal in shape. Plate **463a** is attached to mounting member **423** (not shown) and plate **463b** is attached to mounting member **428**.

[0035] For those trusses **420** connected to collar link points, a modification (not shown) may be made for plates **463a** and **463b**. The portions of plates **463a** and **463b** below the line between points **466** and **467** are eliminated to prevent these portions from interfering with the operation of the shaft **20** and collars **30**. As a result, there are two gaps **411** in Figure 5B, for each respective area **410**. Each gap **411** is approximately the size of the portion of plate **463a** or

463b below the line between points **466** and **467**, and may be closed with a flexible fabric or with attachments on the shaft itself.

[0036] Each pair of plates in Figure 7 is symmetrical with respect to axis of symmetry **470**. For example, the portions of plate **460a**, not visible in Figure 7 because plate **460a** is mounted to the front side of truss **420**, are positioned in a mirror image of the portions of plate **460b** that are visible in Figure 7. There is overlapping of the plates in Figure 7. For example, portions of plate **461a** overlap portions of plate **460a** and portions of plate **460b** overlap portions of plate **461b**. The thickness, or distance between the front and back sides, of truss **420** helps provide the separation between overlapping plates needed for respective plates to slide over and past one another, as described below. The thickness may be tailored on individual assemblies and overlap sides varied to better approximate a typical foil cross-section to the propeller blade. Multiple assemblies **455** are connected to form blade **400** shown in Figures 5A and 5B. To do this, pivotal connections are made at corresponding blade link points. For example, for an assembly **455** (not shown) positioned to the left of assembly **455** in Figure 7, blade link points **435** and **432** would be pivotally connected to blade link points **434** and **437** for assembly **455** in Figure 7.

[0037] Figure 8 is a back view of the plate assembly **455**, in an expanded configuration, corresponding to the area **410** shown in Figure 5B. The following discussion should be considered in light of Figures 5B, 6D, 7, and 8. Figure 8 shows the disposition of the plates described in Figures 7 after truss **420** is moved to the expanded position shown in Figure 6D. In

Figure 8, the plates present the greatest surface area. There is no overlapping between plates **461a** and **461b** and plates **462a** and **462b**. Plates **460a** and **460b** and plates **463a** and **463b**, respectively, partially overlap. In Figure 8, all of plate **460a** is visible, and line **464** shows the overlap between plates **460a** and **460b**. In Figure 8, all of plate **463b** is visible, and line **465** shows the overlap between plates **463a** and **463b**.

[0038] The following should be considered in light of Figures 5A through 8. It should be understood that the truss **420** can have more or less than the four pairs of linking members **450** and associated mounting members shown in Figures 6A through 6D. For example, truss **420** could have three, five, or six pairs of linking members **450** and three, five, or six pairs of associated mounting members, respectively. It also is understood that the number of plates can vary accordingly. For example, in the previous example, a respective assembly **455** could have three, five, or six pairs of overlapping plates.

[0039] The present invention can be applied to a number of propeller or blade applications. For example, the present invention can be used in applications providing propulsion for transportation units including, but not limited to, aircraft, waterborne vessels, and submersible vessels. In addition, the present invention can be used in rotational fans or blowers.

[0040] Thus, it is seen that the objects of the present invention are efficiently obtained, although modifications and changes to the invention should be readily apparent to those having ordinary skill in the art, which modifications are intended to be within the spirit and scope of the invention as claimed. It also is understood that the foregoing description is illustrative of the

present invention and should not be considered as limiting. Therefore, other embodiments of the present invention are possible without departing from the spirit and scope of the present invention.